LAND MOBILE BAND COMPARISON - PROPAGATION EFFECTS

Task 9, Technical Aspects and Analysis of Briefs, Mobile / Fixed Study Group, 406-960 MHz Policy Determination

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1. Introduction

As part of the analysis of briefs and other documentation relating to the establishment of Canadian spectrum policy for the 406-960 MHz band, a comparison was required of radio coverage in the allocated or proposed VHF and UHF land mobile bands. Accordingly, this study of propagation aspects was undertaken.

Two propagation models were used to estimate the terrain effects on coverage in the three bands: the Egli model of an urban path, and the Longley-Rice irregular terrain model (1,2). The Egli model gives frequency - independent estimates of field strength. The irregular terrain model uses a median terrain irregularity parameter Δh; five different types were considered (see Section 6). For comparison of actual radio systems, a detailed terrain model can be used to calculate path loss quite accurately, (2). Similarly, system loss may be found if antenna gain and circuit losses are known, (see Annex A). However, the comparisons shown here, using calculations of median path loss, should be valid on average.

Several fixed parameters were used: ground conductivity 0.001 S/m, permittivity 15, radiated power 100 W, transmitting antenna height 30 m above ground, receiving antenna height 2 m. For the antenna heights chosen, ground conductivity and permittivity have a small effect at 150 MHz, and a negligible effect at the two higher frequencies. It was assumed that both antennas have the same polarization; also that they are lossless, isotropic and have unity gain. These assumptions are valid for comparison purposes, although for a known radio circuit, system loss will generally not equal path loss (see Annex, A).

Using the above parameters, path loss and field strength were calculated as functions of range. For example, see Figure 1 for 460 MHz over rolling terrain. Service radius was derived from such curves using two distinct criteria: (a) field strength and (b) available power from the receiving antenna. These were chosen to be equivalent at 500 MHz: E=30 dB (μV/m) and P_A = -131.2 dBW (see Annex, B). The results are presented in Sections 2 and 3 respectively.

2. Field Strength Criterion

The parameter commonly used for comparison of systems at lower frequencies, where antennas are usually small relative to the wavelength, is the field strength at the receiver. If one assumes that a field strength of 30 dB (μV/m) or 31.6 μV/m is required, the results shown in Figure 2 are obtained.

Figure 2(a) shows the service radius for 100 W radiated power. Most terrains show increased range with increasing frequency. The urban (Egli) model (□) shows no change, however, and over very rugged terrain (x) the service radius is less at the higher frequencies.

Figure 2(b) shows the transmitted power required to give a service radius of 50 km. As would be expected from 2(a), less power is required at the higher frequencies for the smoother terrain. The very rough terrain shows the opposite effect, and no change with frequency is found for the urban model. For hilly terrain (•), the lowest power requirement is at 460 MHz.

3. Available Power Criterion

In the frequency range of concern here, the available power is probably the preferred parameter to use for comparison of systems operating at greatly differing frequencies, since it includes the effect of the smaller antennas used at the higher frequencies.

Figure 3 shows the results when a requied power of -131.2 dBW is assumed.

Figure 3(a) shows the service radius for 100 W radiated power. All terrain models show decreased range with increasing frequency, although the effect is greater for urban and mountainous terrains.

Figure 3(b) shows the transmitted power required to give a service radius of 50 km. All terrains, particularly the urban and rugged models, show increased power requirements at the higher frequencies. At 50 km over average terrain, about 6 dB more power is required at 460 MHz than at 150 MHz, and a further increase of about 4-5 dB would be needed at 850 MHz. At ranges shorter than 50 km the difference with terrain was found to be even greater, eg for a service radius of 10 km at 850 MHz, urban loss (□) is about 12 dB greater than the loss for rolling terrain (△).

4. Conclusion

A. Range and Terrain Effects

The basic calculation obtained from the terrain models is that of median path loss, which does not represent any particular path. Calculated path loss increases rather slowly with range, so that a few decibels change in path loss may mean a considerable change in estimated service radius (see Figure 1). Small differences in estimated service radius or required power are therefore not significant.

The results show that median path loss and required power increase with terrain roughness greater than 60 m. At the higher frequencies, the urban (Egli) model corresponds approximately to an irregular terrain with Δh = 150 m. Changes in Δh have a greater effect on required power at, say, a service radius of 10 or 30 km than they do at 50 km.

B. Height Gain

Antenna height gain will be greatly affected by antenna clutter, which has not been considered in this study. However, as an indication of the expected effect of transmitter antenna height, Figure 4 shows the calculated path loss vs. antenna height for the six terrains, at 50 km range and 460 MHz.

C. Frequency Effects

The conclusions to be drawn from the results of Sections 2 and 3 respectively differ due to the different criteria used. From Section 2, using a field strength of 30 dB (μV/m) to define service radius, one would conclude that only over very rugged terrain would the service radius be decreased at higher frequencies (or conversely, that the power requirements would be greater).

However, the results of Section 3, i.e. using the available power to define service radius, probably present a truer comparison of systems in the three land mobile bands then do those based on field strength. On that basis, for a given radiated power, coverage is less at the higher frequencies. Conversely, more power is required for a given service radius. These effects are more pronounced in an urban environment or in very rough terrain, and somewhat less at shorter ranges.

5. References

1. Longley, A.G. and P.L. Rice, Prediction of Tropospheric Radio Transmission Loss Over Irregular Terrain - A Computer Method - 1968. ESSA Technical Report ERL 79-ITS 67, (July 1968).

2. Palmer, F.H., Review of Propagation in the 470-890 MHz Band with Emphasis on Land Mobile and Cellular Systems. CRC Report No. 1288, February 1976.

3. The Concept of Transmission Loss in Studies of Radio Systems. Recommendation 341, p. 82, Vol. I of XIIIth Plenary Assembly, CCIR, Geneva 1974.

4. Transmission Loss in Studies of Radio Systems, Report 112, p. 85 ibid.

6. Figures

Figure 1 shows, as an example, the path loss and field strength versus range from the transmitter, calculated for 460 MHz over rolling terrain (Δh = 60 m).

Figures 2 and 3 show results of the calculations of (a) service radius for a radiated power of 100 W and (b) radiated power required to give a service radius of 50 km. Points are plotted for 150, 460 and 850 MHz and for the following terrain models:

Urban Model

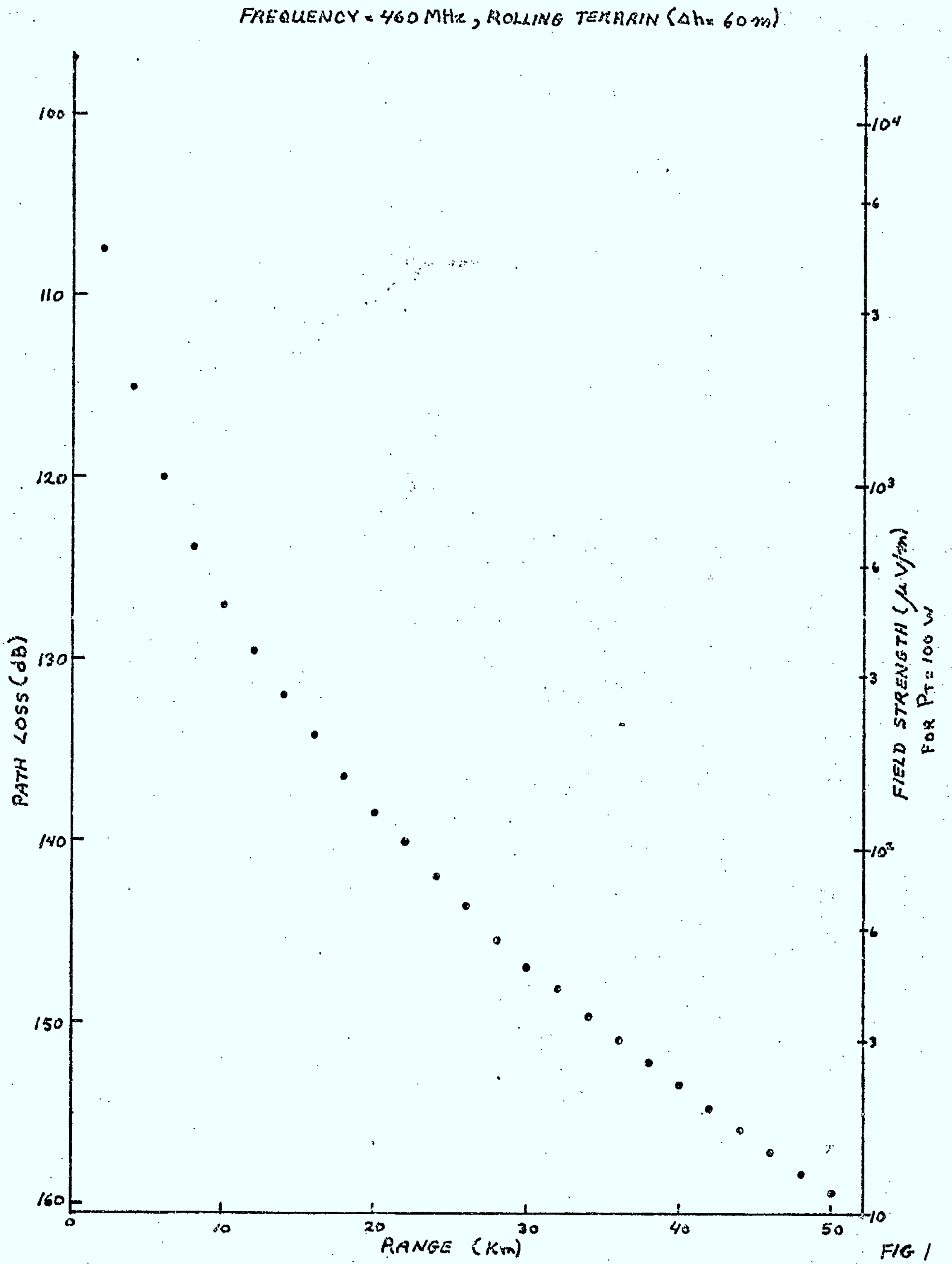
□

Irregular Terrain Model

	Terrain Type	Δ h (m)
+	Smooth	12.5
o	Slightly rolling	30.
△	Rolling	60.
●	Hilly	115.
×	Mountainous	225.

Figure 2 shows the results using a service radius defined by a field strength of 30 dB (μV/m). The results of Figure 3 correspond to a service radius defined by -131.2 dBW.

Figure 4 shows path loss at 50 km, for 460 MHz and a receiving antenna height of 2 m, versus transmitting antenna height.



FREQUENCY = 460 MHz, ROLLING TERRAIN (Δh = 60 m)
PATH LOSS (dB)
100
110
120
130
140
150
160
0
10
20
30
40
50
RANGE (Km)
FIELD STRENGTH (μV/m) FOR P_T = 100 W
10^4
6
3
10^3
6
3
10^2
6
3
10

FIG 1

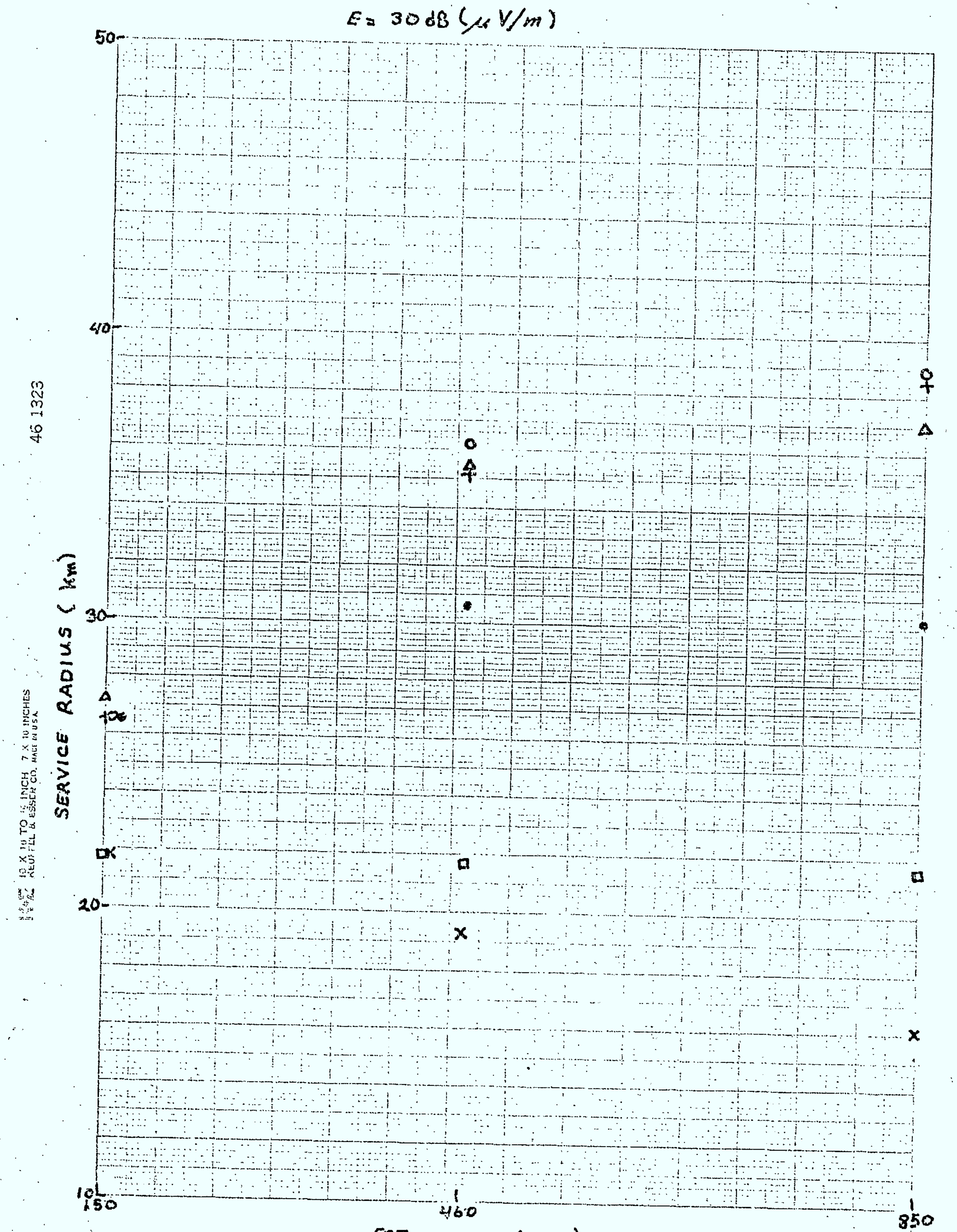
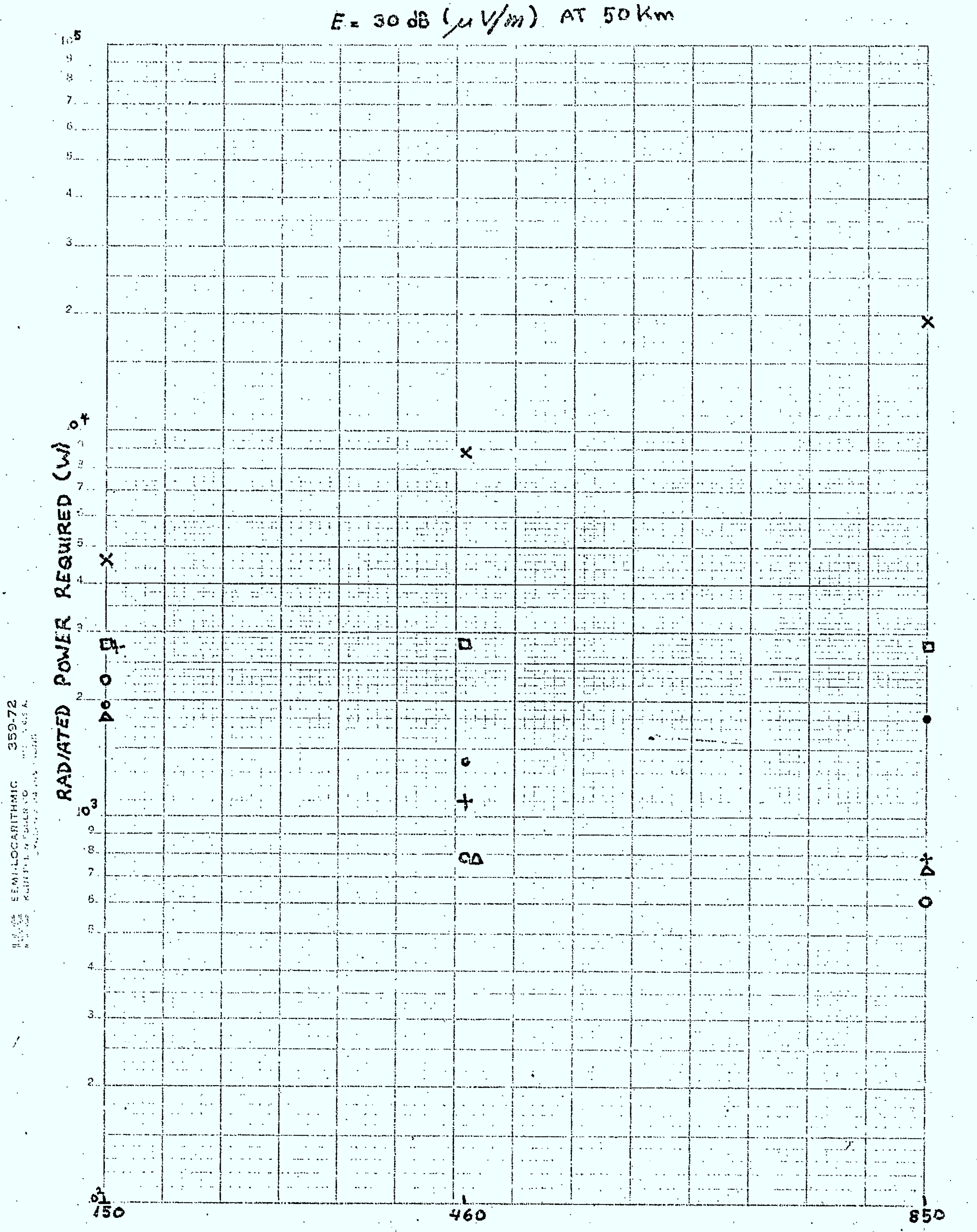
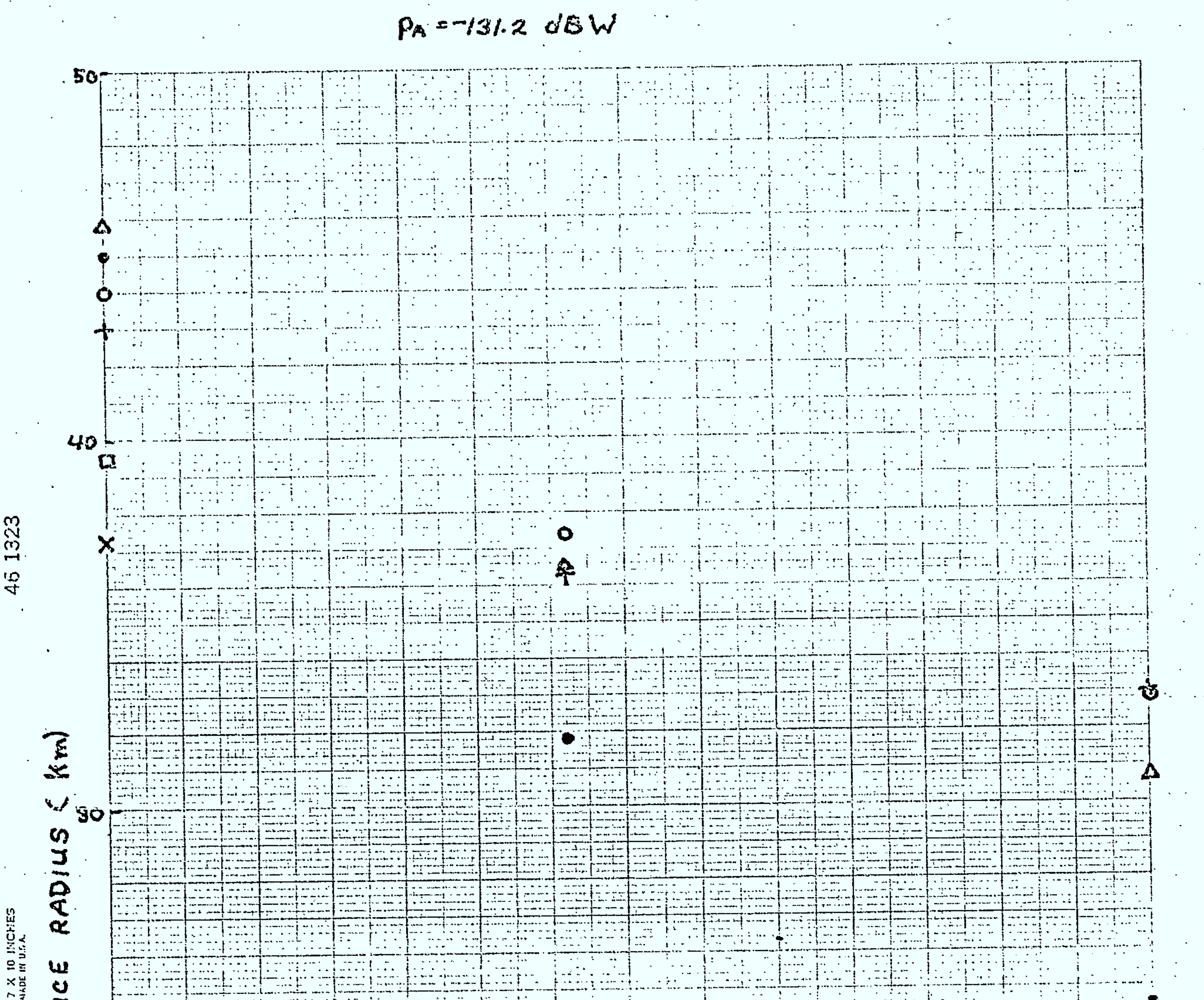

E = 30 dB (μV/m)
SERVICE RADIUS (km)
FREQUENCY (MHz)
50
40
30
20
10
150
460
850
46 1323
10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIG 2a



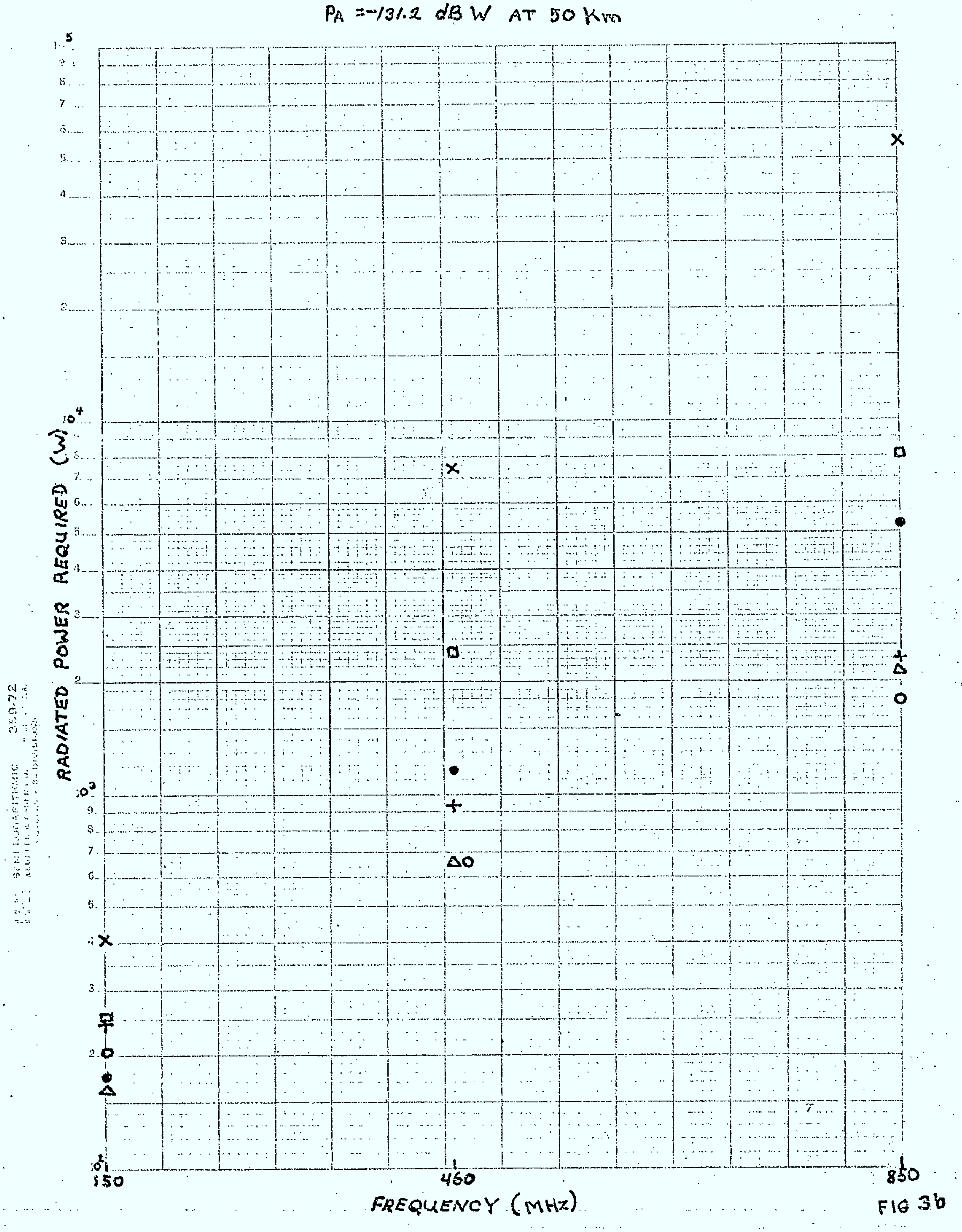
E = 30 dB (μV/m) AT 50 Km
RADIATED POWER REQUIRED (W)
FREQUENCY (MHz)
150
460
850
SEMI-LOGARITHMIC 359-72

FIG 2b



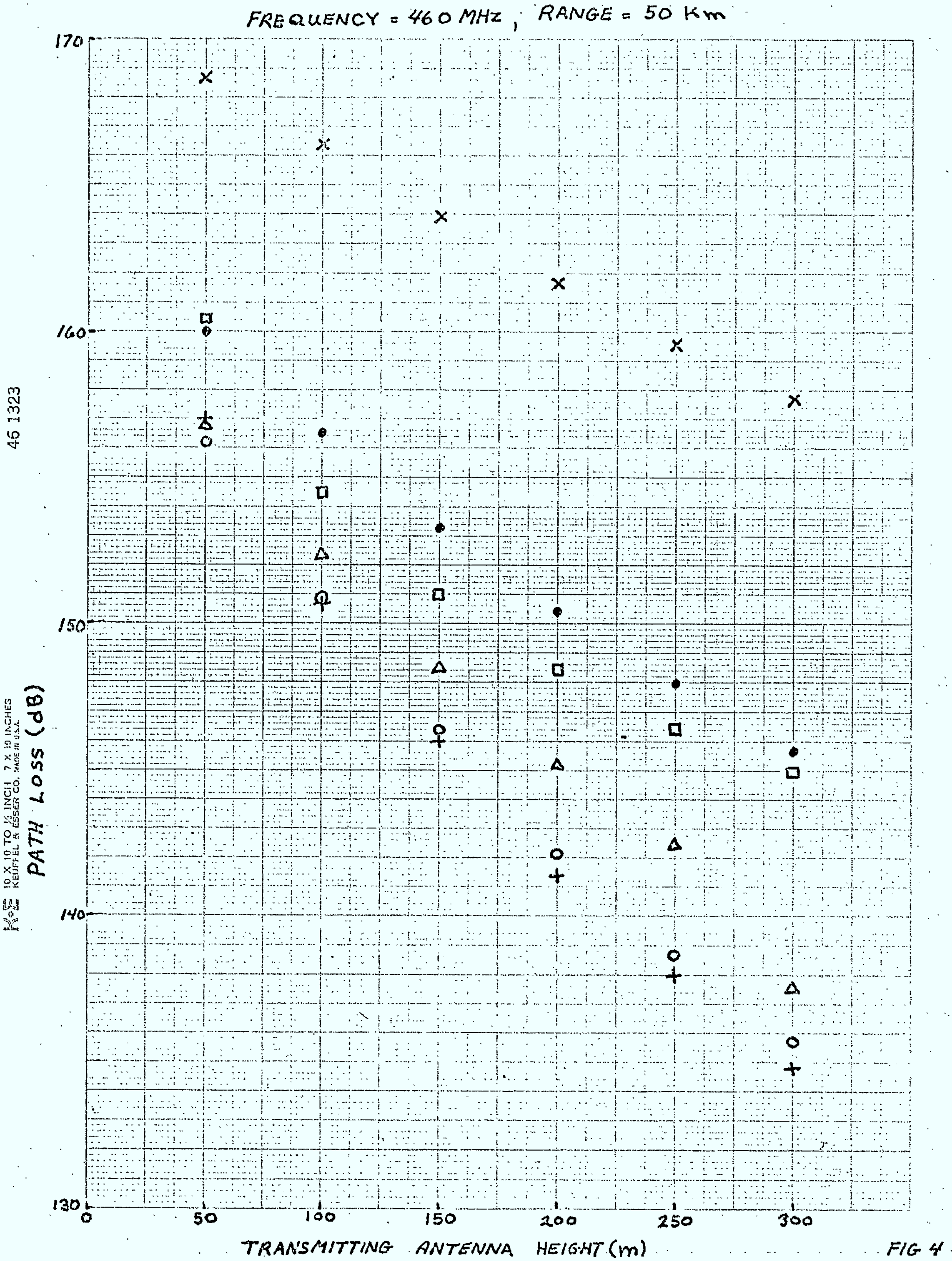
P_A = -131.2 dBW
50
40
30
20
10
150
460
850
SERVICE RADIUS (km)
FREQUENCY (MHz)
46 1323
10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIG. 3a



P_A = -131.2 dBW AT 50 Km
RADIATED POWER REQUIRED (W)
FREQUENCY (MHz)
150
460
850

FIG 3b



FREQUENCY = 460 MHz , RANGE = 50 Km
PATH LOSS (dB)
170
160
150
140
130
0
50
100
150
200
250
300
TRANSMITTING ANTENNA HEIGHT (m)
10 X 10 TO 1/2 INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1323

FIG 4

7. Annex

A. Path Loss

The definition of path loss or basic transmission loss L_b used here is that of CCIR Recommendation 341 (3), i.e. the ratio in decibels of the power radiated from the transmitting antenna to the power available from the receiving antenna into a matched load, assuming both antennas to be lossless and isotropic. The transmission loss L, as defined, includes the path antenna gain G_p, i.e. $L = L_b - G_p$, and so is generally less than the path loss.

The system loss L_s of a radio circuit is the ratio of the power input P_T at the antenna terminals to the power P_A available from the receiving antenna. It therefore includes all losses except transmission line losses:

$$L_s = P_T - P_A = L + L_c,$$

where L_c is the combined loss of the antenna circuits. CCIR Report 112 (4) suggests that the loss concept is preferable to that of field strength for comparison of systems. In the present study, $L_c = G_p = 0$, therefore

$L_b = L = L_s = P_T - P_A$.

B. Field Strength

The field strength at the receiver is given by

$$E = P_A + 10 \log (n/A),$$

where E = 20 log e (μV/m), n = 377 ohms and the effective area of the receiving antenna A = $\lambda^2/4\pi$. Therefore

$$E = P_A + 20 \log f \text{ (MHz)} + 107.22 .$$

For E = 30 dB (μV/m) and f = 500 MHz, P_A = -131.2 dBW, which is the available power criterion used in Section 3. For P_T = 20 dBW or 100 W, this corresponds to a path loss of 151.2 dB.